Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis of Low Latency Data Access from LEO Meteorological Satellites

Presented to CGMS-52 Working Group I session, agenda item 5.6

Coordination Group for Meteorological Satellites

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Presentation prepared in response to CGMS Future Direction IoT theme and Actions WGI/A51.07, WGI/A51.08.

TG	AGN item	Action #	Description	WP
LLDA	5.1	CGMS Future Direction	Future Information Technologies - Internet-of-Things	*CGMS-52-WGI-WP-06*
LLDA	5.6	WGI/A51.07	Distribute a summary of the SWOT analysis on Low Latency Data Access from LEO meteorological satellites to the remaining CGMS Working Groups.	*CGMS-52-EUMETSAT-WP-13*
LLDA	5.6	WGI/A51.08	Analyse potential role of satellite platform as a service (SPaaS), considering current and expected providers, internet connection speed, hosted instruments specifications (size/weight/power), orbit type, satellite lifetime and cost breakdown. Report to CGMS-52.	*CGMS-52-EUMETSAT-WP-13*

CGMS Future Direction

Background

CGMS-50 plenary (15-17 June 2022) endorsed the proposal by the CGMS Secretariat for considerations for the future direction of CGMS (Ref. CGMS-50-CGMS-WP-20 and CGMS-50-CGMS-WP-38) in view of the changing environment and in order to take stock of the current and future CGMS activities.

This activity is needed to:

- Take into account the impact of the changing environment and user requirements, and the need for CGMS to remain user-driven and operational;
- Take into account changes in CGMS leadership;
- Set the priorities for the next 10 years and beyond; and
- Regularly assure CGMS activities address issues of importance to space agencies and users in the long term.

CGMS Future Information Technologies - Internet-of-Things

Scope

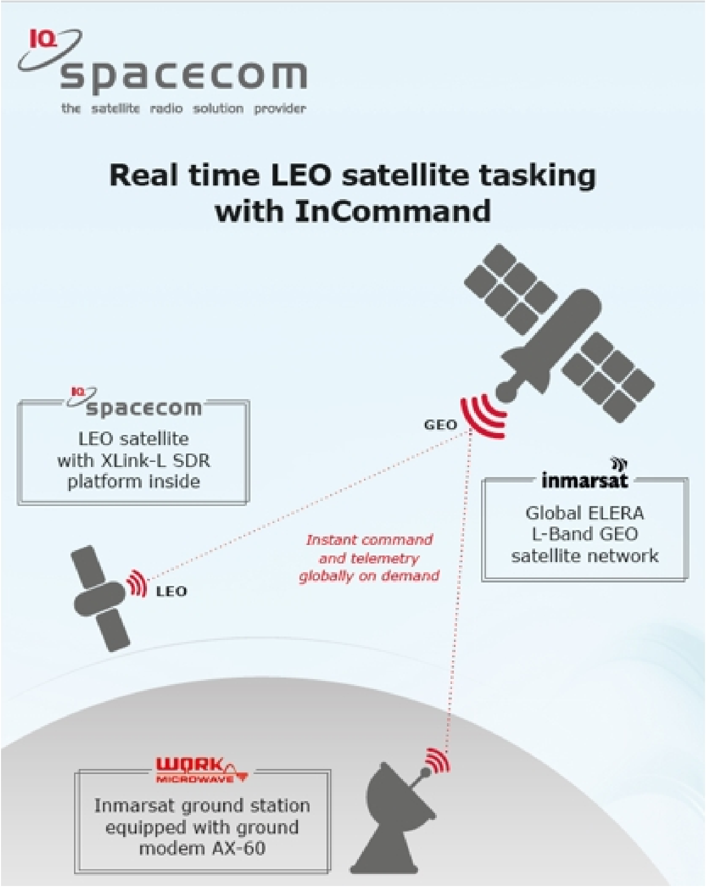
Internet-of-Things can be defined as “the connection of devices within everyday objects via the internet, enabling them to share data” (Oxford Dictionary). The scope of Internet-of-Things applications, commonly referred to as IoT is wide, englobing household’s appliances to connected cars, airplane, etc.

This CGMS paper narrows the spectrum of IoT applications to focus primarily on IoT for Earth Observation, noting the two following aspects of importance to CGMS WGI:

i. **IoT applications for LEO satellites**, which enable data connectivity for LEO meteorological satellites. A CGMS WGI application example would be direct broadcast, enabling transfer of payload data from LEO meteorological satellites in near real time;

ii. **IoT applications for ground-based devices**, which enable data connectivity for ground-based meteorological devices. A CGMS WGI application example would the DCS system, enabling transfer of ground-based weather station data via meteorological GEO satellites.

(i) IoT providers enabling connectivity to LEO satellites: GEO IoT commercial providers



Internet on LEO satellite is now a reality with the availability of GEO IoT solutions. The inter-satellite links between a LEO and GEO using beams are RF based signal. NASA is working on laser inter-satellite communication for the next GOES generation.

For example, IQ spacecom offers a lightweight transponder (200 grams) that provides internet connectivity to the Inmarsat GEO fleet. This capability provides bi-directional connectivity to the spacecraft at 200 kbps.

Some SPaaS companies (e.g. Loft Orbital), offers this transponder as pre-built COTS on the Longbow platform (e.g. Airbus OneWeb platform).

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(i) IoT providers enabling connectivity to LEO satellites: GEO IoT commercial providers

Price:
The current price of the GEO relay service for a LEO satellite is approximately 1k/euros/month per GB transferred.

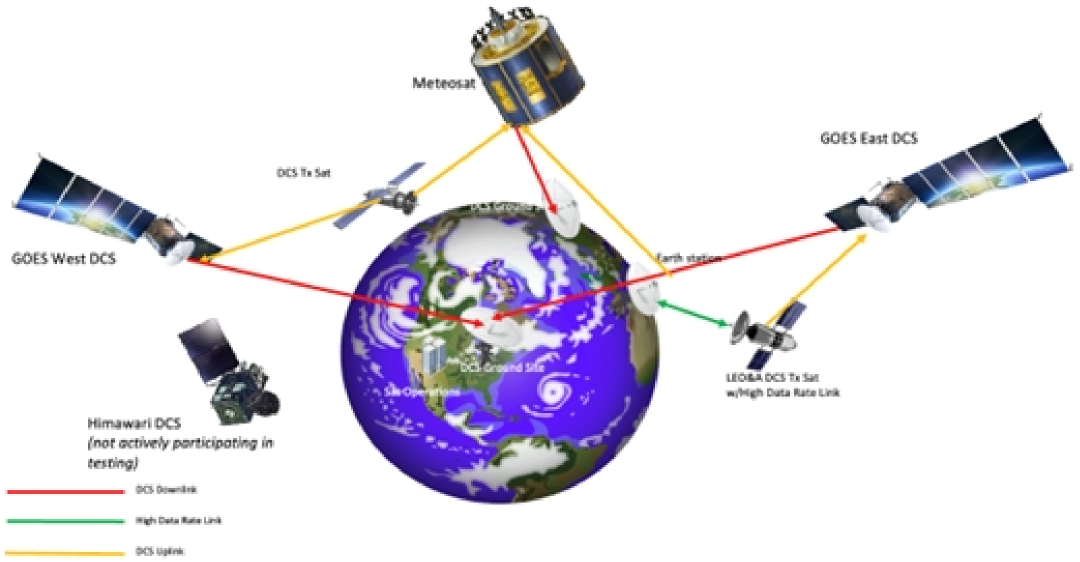
A non-exhaustive list of IoT providers to LEO:

IoT providers	Constellation	Link to material
Viasat	GEO	ARBALEST program
Inmarsat	GEO	IDRS – see IoT4EO presentation
SES Astra	MEO	Via O3b mPOWER – see IoT4EO presentation
Neosat	GEO	Home webpage
-	LEO	No LEO to LEO providers yet

(i) IoT providers enabling connectivity to LEO satellites: DCS

Commanding of LEO satellites via DCS:

- NOAA/NESDIS initiated this the Satellite DCS Use Concept Validation project to determine if a satellite can interface effectively within the DCS;
- Project demonstrated that LEO satellites can successfully interface with the Data Collection System (DCS) receivers (DCPR) and provide a low-rate data (100, 300, or greater bps) service to satellite users;
- Project also successfully demonstrated LEO commanding capability via GOES.

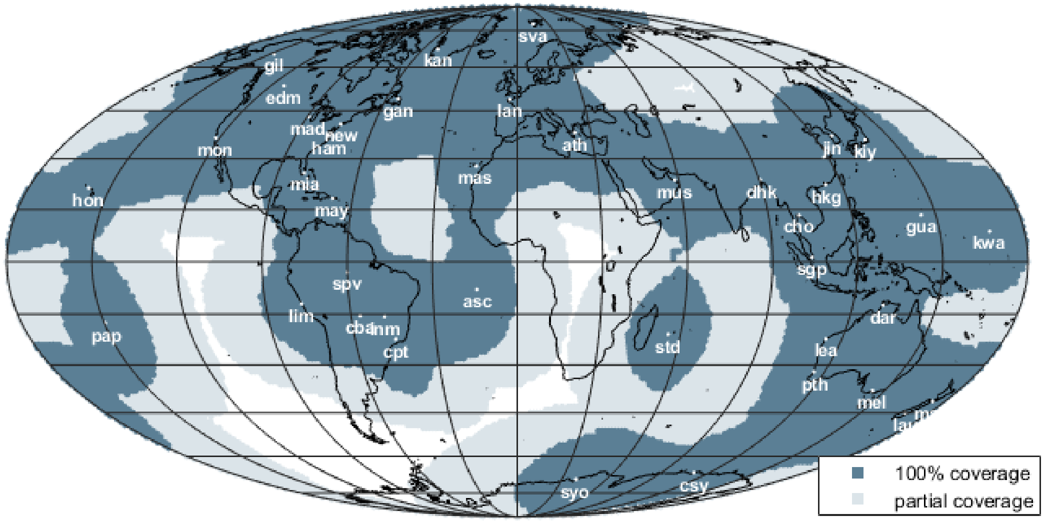


(i) IoT providers enabling connectivity to LEO satellites: DBNET network of ground stations

DBNET:

The DBNET network is a dedicated infrastructure for acquisition of direct broadcast that has been growing during the last decades. Although allowing connectivity from LEO satellites, this network is passive (no uplink possibility to LEO satellites).

Today, direct broadcast reception allows for almost full coverage of the globe for the reception of sounding services. The cost of a pass acquisition from a subsidised DBNET station is around ~$10 per pass.



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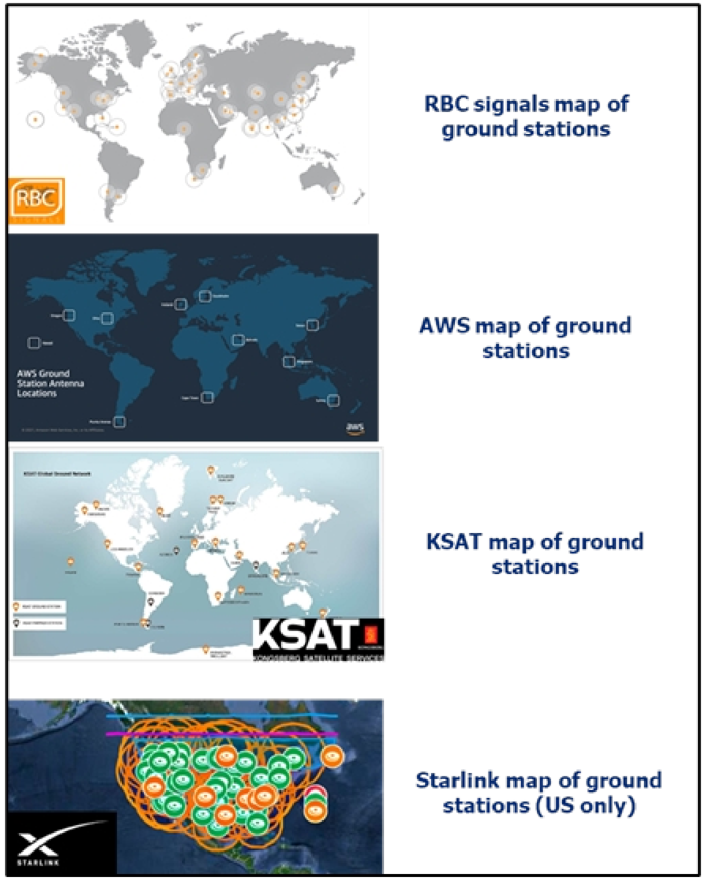
(i) IoT providers enabling connectivity to LEO satellites: commercial network of ground stations

Commercial network of ground stations:

These stations can offer either passive or active (i.e. downlink with possibility of uplink). The cost of a pass acquisition from a private ground station is around ~$100 per pass.



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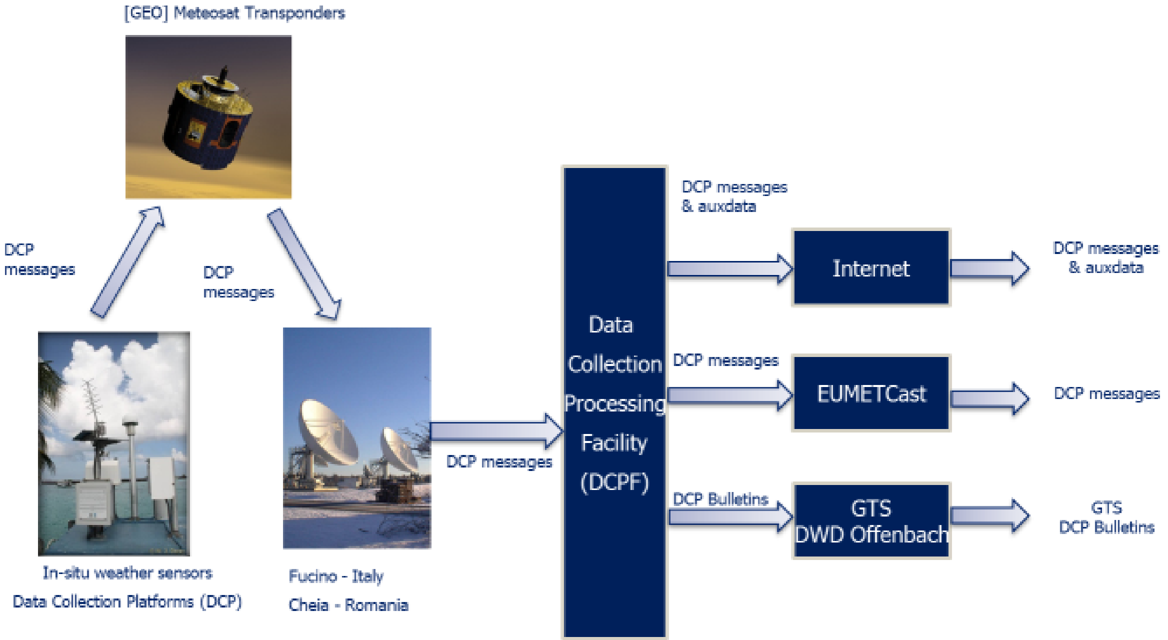
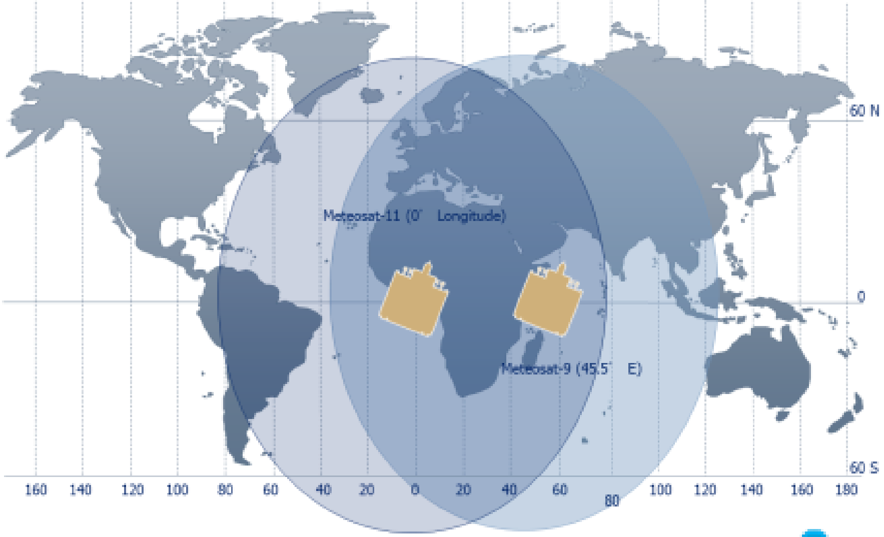
(ii) IoT applications for meteorological ground-based devices: GEO IoT providers

<u>GEO IoT commercial providers:</u> well matured market. Internet is provided via parabolic antenna, usually provided alongside a modem by the GEO IoT providers. Similar providers list as in slide 6.

<u>Data Collection System (DCS)</u>

DCS enables Data Collection Platform (DCP) Operators to retransmit DCP data collected from remotely located platforms to their own reception stations and to the Global Telecommunication System (GTS) community of the World Meteorological Organisations (WMO).





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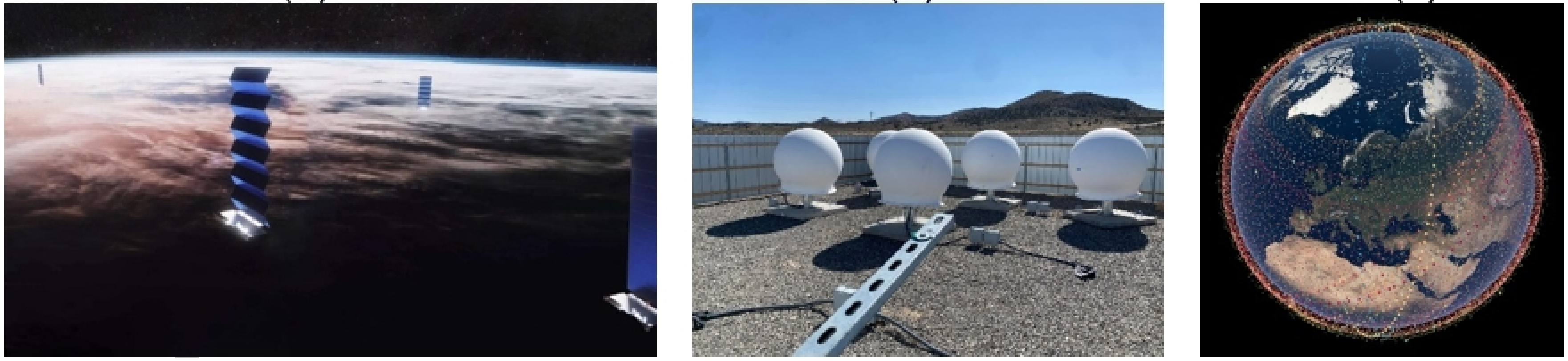
(ii) IoT applications for meteorological ground-based devices: LEO IoT providers

LEO IoT commercial providers: number of providers exploding (new space). Revisit time can be an issue, especially for new constellations with limited number of satellites, ranging to several hours.

The number of relay satellites for a LEO constellation can range from a small number to several thousand (12000 satellites for SpaceX Starlink V1 system with up to 42000 for Starlink V2 system).

(a) (b) (c)



SpaceX Starlink constellation with (a) artist view of constellation (image credit SpaceX) (b) typical Starlink ground station gateway (image credit Reditt) (c) Visualisation of the 30 000 planned satellites from the Starlink Generation 2 constellation as of 2022. Different sub-constellations are illustrated with a different colour (image credit ESO).

SWOT Analysis executive summary

The core meteorological satellite systems in LEO orbits, and other operational satellite systems where applicable, should ensure low latency data access of imagery, sounding, and other real-time data of interest to users. Application areas where low latency and availability is suitable include Severe Weather Monitoring, Nowcasting and Short- and Medium-Range Numerical Weather Prediction. Other application areas could also benefit from very low latency products, e.g. ionospheric monitoring.

Today, LEO meteorological satellites have two distinct services for providing low latency data to users:

- Global service: where the full orbit data is stored on-board and served at the pole(s);
- Regional or local service: real time dissemination of instruments data to a network of direct broadcasts stations.

The goal of this CGMS paper is to analyse the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of current LEO weather satellites systems to identify how low latency data access solutions could help in improving timeliness globally.

This SWOT analysis paper follows a previous CGMS paper [CGMS-51-WGI-WP-06] which focuses on low latency data access solutions opportunities for LEO weather satellites systems.

S Strengths	W Weaknesses	O Opportunities	T Threats
Maturity: • Well established LEO weather space segment • Well established ground segment worldwide for regional and global missions • Well established coordination at CGMS, DBNET and WMO levels. • Well established standards (e.g. CCSDS) • Well established data distribution mechanisms to users • Well-established data exchange cooperation between agencies. **End2End ownership of data chain:** • Owned space and ground equipment, giving more control over assets. Limited reliance on private sector in the data chain.	**Downlink and Latency:** • High latency over regions without direct broadcast, e.g. gap over oceanic regions • Duplicated products between regional and global products • Data rate limitation in direct broadcast X band **Cost:** • Owned / dedicated ground equipment leading to higher costs. • Communications links to multiple ground stations required. **Commanding:** • No uplink outside polar regions Limited monitoring of space assets outside of polar regions	**GEO relay services:** • Global availability of data worldwide through GEO relay constellation. • Maturing market with Inmarsat, SES Astra and many others **LEO relay services:** • Global availability of data worldwide through LEO relay constellation. • Low maturity, many new markets appearances. **Ground stations as a Service:** • Regional availability of data through a global network of ground stations as a service. • High maturity. **Satellite Platform:** • Built-in GEO relay transponder with on board processing. • Satellite Platform as a Service (SPaaS), covering launch to operations. **Cloud services:** • Complete suite from raw data to products available within most latency requirements. • User internet capability will determine volume and latency.	**Dependence on private sector:** • Reliance / dependence on a commercial service for the end2end ownership of data chain • Volatile relay satellite operators market **Cost:** • GEO relay constellation bandwidth cost (e.g. ~1 Mbps for 2 k$/month as a minimum) **Frequency protection:** • Relay constellation increase pressure on the frequency spectrum **Security:** • For SPaaS Security risk via uplink commands to CGMS satellite. **Coordination & Standards:** • Role of CGMS inter agency coordination unclear for data exchange mechanism which may change (e.g. via cloud?) • Little to no standards for inter-satellite communications.

For further details see CGMS-52-EUMETSAT-WP-13

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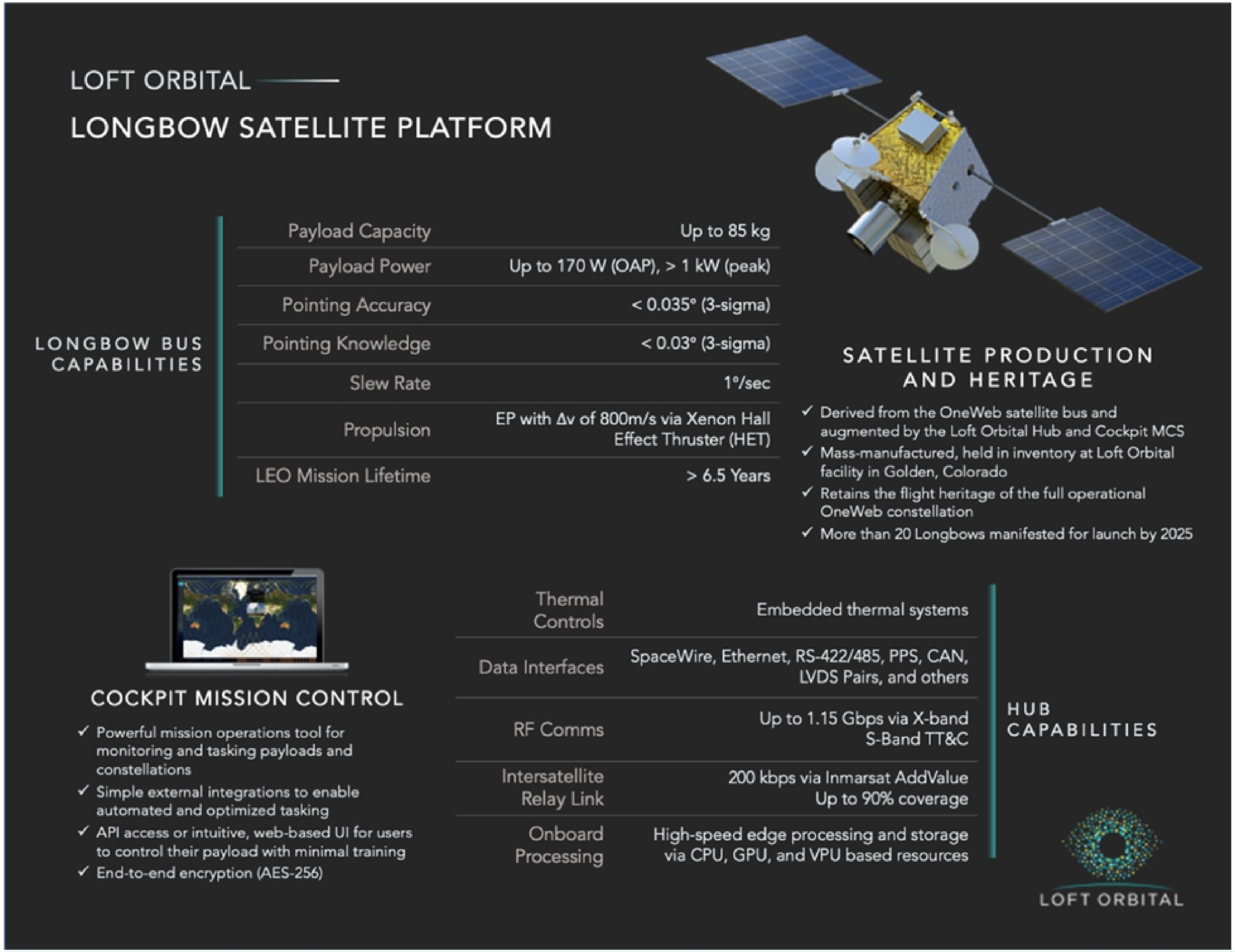

Satellite Platform as a Service (SPaaS)

- Airbus platforms manufactured each day from Toulouse and US lines.
- 200 kbps internet built-in as COTS
- SpaceX launch within 6M after receiving payload
- Competitive cost covers payload integration + launch + operations

➔ Highly relevant for proto-flight model (CGMS agencies usually keep control on operations)

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SWOT summary: comparison of IoT solutions for LEO payload downlink

IOT solutions for LEO payload downlink	Cost assumption	Comment
Direct Broadcast – subsidized station	~$10* per pass	Subsidised cost considering ground station infrastructure already built. Estimate only covering station exploitation and maintenance cost. This cost assumption also assumes a full usage of a reception chain with acquisition of all DBNET satellites (around 1000 passes per month).
Direct Broadcast – commercial station	~$100 per pass	Cost considering a direct broadcast acquisition by commercial ground station. Cost assumption for around 1000 passes per month.
GEO IoT	~$1k per GB per month	Flat rate for GEO IoT solution for LEO payload downlink. Costing estimate does not reflect potential cost reductions with high volume of data.

LEO data rate (kbps)	Data volume (Kb/14-min-pass)	GEO IoT cost ($/pass)
1	840	0.84
10	8400	8.4
50	42000	42
100	84000	84
200	168000	168
100000	84000000	(not possible, max data rate 200 kbps)

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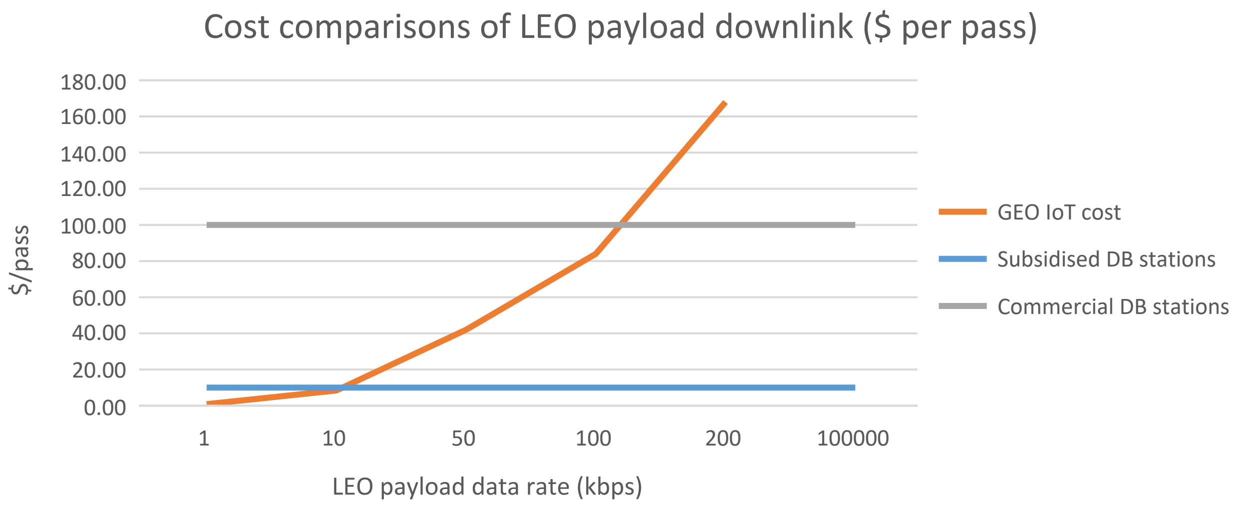
SWOT summary: comparison of IoT solutions for LEO payload downlink



Subsidised direct broadcast stations (e.g. DBNET type) offer the best value for money per Gb transmitted for acquiring LEO satellites that have a payload data rate greater than 10 kbps.

Study conclusions (1)

LEO IoT to complement DCS in polar locations

The current DCS system provides a relay solution to ground-based meteorological devices for latitudes up to 75° (see Figure 6). This study findings show that LEO IoT providers can provide coverage for greater northern and southern latitudes.

Each LEO IoT providers has its specificity. For example, a provider such as Astrosat offers very competitive price while revisit time can be several hours due to the low number of satellites. Another provider such as Starlink offers almost continuous data connectivity with bandwidth up to 100 Mbps, although power consumption and antenna size are relatively important. This study therefore recommends to WGI to conduct an analysis to identify the optimum(s) LEO IoT provider.

Study conclusions (2)

GEO IoT internet to open new mode of operations for LEO meteorological satellites?

Telemetry & Telecommand

Telemetry and Telecommand (TM&TC) operations for LEO meteorological satellites are traditionally executed via polar stations. Although TM&TC downlink operations are possible via direct broadcast stations, live connectivity to the LEO satellite provides the potential to perform TM&TC uplink operations outside ground segment coverage such as:

- Direct commands to the spacecraft for reconfiguration;
- Application-specific commands.

With an increasing debris environment in the LEO orbits, it is now routine for CGMS operators to perform ‘collision avoidance manoeuvres’. Live connectivity to the LEO satellite provides via GEO IoT solutions would allow to perform these manoeuvres live, outside ground segment coverage.

Downlink of LEO meteorological satellites instrument payload

Timeliness

All solutions offer similar timeliness performance, in terms of reception of raw data to the ground.

Coverage:

Almost full disk coverage are offered by GEO IoT and DBNET network with some differences. GEO IoT offers full disk coverage except for polar latitudes. DBNET offers disk coverage with exception of oceanic regions and Africa.

Cost: DB if data rate > 10 kbps

For discussion

More generally, this study also raises the question of the CGMS position to follow regarding the emergence of the “new space” sector.

For sustained innovations (e.g. LEO IoT for DCS), a first option would be to encourage CGMS agencies their adoption.

For disruptive innovations (e.g. internet in space, SPaaS), an option would be to have some level of coordination performed at CGMS. One could indeed see at CGMS level some kind of feedback being brought by agencies trialling or adopting new space technology.

Thank you for your attention

END